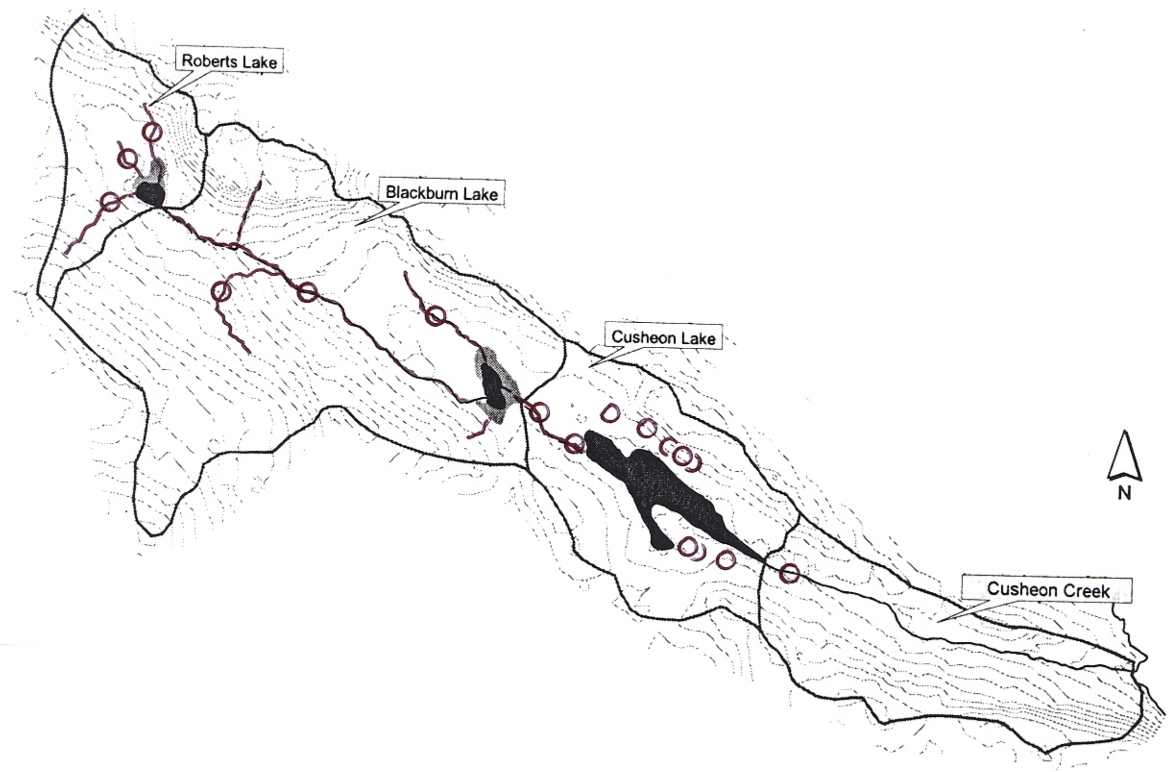
Phosphorus content of certain creeks and lakes in the Cusheon Lake basin, Salt Spring Island, B.C.



2007. September

By: John B. Sprague, Ph.D.
Sprague Associates Ltd.
474 Old Scott Road
Salt Spring Island, B.C.

A background report for
The Cusheon Watershed Management Plan
and Steering Committee
Salt Spring Island, B.C.

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by John B. Sprague, Sprague Associates Ltd., Salt Spring Island, B.C. V8K 2L7
Background Report for the Cusheon Watershed Management Plan and Steering Committee
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Summary

(1) This is one of five background technical reports, for assessing the nutrient input to Cusheon Lake. This report focuses on phosphorus content of two lakes and some small creeks which are upstream of Cusheon Lake. The main purposes are to ascertain the phosphorus levels in the lakes and to asses the importance of the creeks as a source of nutrient. The work was carried out during nine months starting in August 2004.

(2) In Roberts Lake, on six days when the lake was mixed, the average concentration was 16.5 ppb. One measurement in Blackburn Lake, combined with six measurements by the B.C. Ministry of the Environment in 1981, gave an average value of 16.3 ppb during the season when the lake is mixed.

(3) Roberts Lake is the first in the three-lake system. The creeks feeding this lake drain a small area, and in the early autumn their flows were low. Their *concentrations* were about 50% of the concentrations prevailing on the same day, further downstream in the system in the lower parts of Blackburn Creek. (Blackburn Creek runs to Blackburn Lake, then continues to Cusheon Lake, the downstream lake of the system.) Because the creeks at Roberts Lake are small, their *load* of phosphorus was only 1% to 8% of the load in Blackburn Creek.

(5) During the winter and early spring, creeks feeding Roberts Lake had surprisingly high concentrations and loads of phosphorus. This was judged from four samples during these seasons. They had concentrations close to 30 ppb, which was about one-half of, or equal to, the concentrations in Blackburn Creek as it discharged into Cusheon Lake. The load carried by the Roberts creeks was about one-third of the load carried by Blackburn Creek, in the same winter and spring seasons.

(6) A hillside that had been clear-cut four years previously, had apparently grown adequate low bushes and ground-cover to control erosion and phosphorus runoff. In springtime samples, the creek draining the clear-cut had water that was clear, with normal phosphorus concentrations of about 10 ppb. The concentration was about the same as, or half as high as, the phosphorus concentration in Blackburn Creek on the days of sampling. Because the creek was small, it contributed a negligible phosphorus load that was only 0.5% of the load carried by Blackburn Creek.

(7) Two streams of runoff water from a new road off Blackburn Road were sampled once by single samples. Total phosphorus concentrations were higher than in Blackburn Creek, the destination of the runoff, but because of their small flows, the phosphorus load was less than a tenth of the load carried by Blackburn Creek. This single small evaluation does not give an adequate assessment of nutrient contributed by the major construction activities for the road.

(8) Hitchcock Creek is a small creek that crosses Blackburn Road, half a kilometre from Blackburn Creek. The flow of Hitchcock Creek averaged 10% of the Blackburn flow for the ten occasions when samples were taken, but the relative flows varied eighteen-fold.

The phosphorus concentrations in Hitchcock Creek averaged 72% of those in Blackburn Creek. Because of this lower concentration and much lower average flow, the average load of phosphorus carried by Hitchcock Creek was only 7% of the loads in Blackburn Creek. Both relative concentrations and relative loads were extremely variable.

(9) Along the most downstream section of Blackburn Creek that bordered a modular-home park, a small number of measurements of *dissolved* phosphorus indicated an average increase of 24 grams of phosphorus per day. That gave some confirmation of an earlier theoretical estimate of a 21-gram increase as the result of normal seepage from septic fields at the modular-home park. Changes in *total* phosphorus in the same portion of creek did not provide useful information because they were wildly variable, probably because of erratic amounts of silt in the water, as the result of erosion and turbulent flow that stirred up sediments.

(10) Near the top of Cusheon Creek, where it drains Cusheon Lake, eight samples showed variation in total phosphorus from 18 to 92 ppb. The variation probably resulted from sediment stirred up by turbulence in the creek. Dissolved phosphorus in four samples ranged only from 10.5 to 18.4 ppb. Flow and phosphorus load of the creek varied over three orders of magnitude. The sampling-point was not suitable, and the samples too few, to allow any input/output calculations for the lake.

INTRODUCTION

This is one of five background reports for the Cusheon Watershed Management Plan (CWMPSC 2007). This work was carried out under the auspices of the Cusheon Watershed Management Plan Steering Committee. The overall purpose was to determine the sources of phosphorus input to Cusheon Lake.

The present study had two particular purposes. One purpose was to assess the phosphorus contributions of small creeks in the drainage basin. The information would supplement the one-year study of phosphorus in Blackburn Creek, the largest one in the upper watershed (Sprague 2007b). A second purpose was to measure phosphorus levels in Roberts Lake, the first lake in the chain of three, since it lacked such information.

The intended strategy was to assess the *load* of phosphorus carried by the smaller creeks as a proportion of the load in Blackburn Creek. That would give an indication of the general importance of these minor creeks as a source of nutrient. Samples were taken at representative times during the wet season, but it was not intended to obtain a continual picture of loading throughout the year.

The main findings of the study are reported above in the summary. The remainder of the report provides supporting technical information.

METHODS

Locations

A total of 12 locations were used here (Figure 1, counting all the culverts into Cusheon Lake as one location). Some emphasis was placed on *Blackburn Creek* above and below *Blackburn Lake*, since it carries the most water to *Cusheon Lake.* All the creeks are temporary, with flow dropping to zero or almost zero during the summer drought. "Blackburn" is often abbreviated to "BB" in the names of stations and elsewhere in this report. Roberts Lake and Blackburn Lake were sampled sufficiently to provide information for modelling those lakes (Sprague 2007a).

Roberts Lake inlet creeks. Starting at the northwesterly end of the system (Figure 1), two little creeks feeding into *Roberts Lake* were sampled occasionally *(Roberts North and Roberts West)*. Between them, a runoff channel was also sampled ("*Roberts ruts")*. It was a place where the wheel-tracks of a vehicle trail had become eroded 10 to 30 cm deep into clay, and runoff water was channelled through this bare soil to the lake.

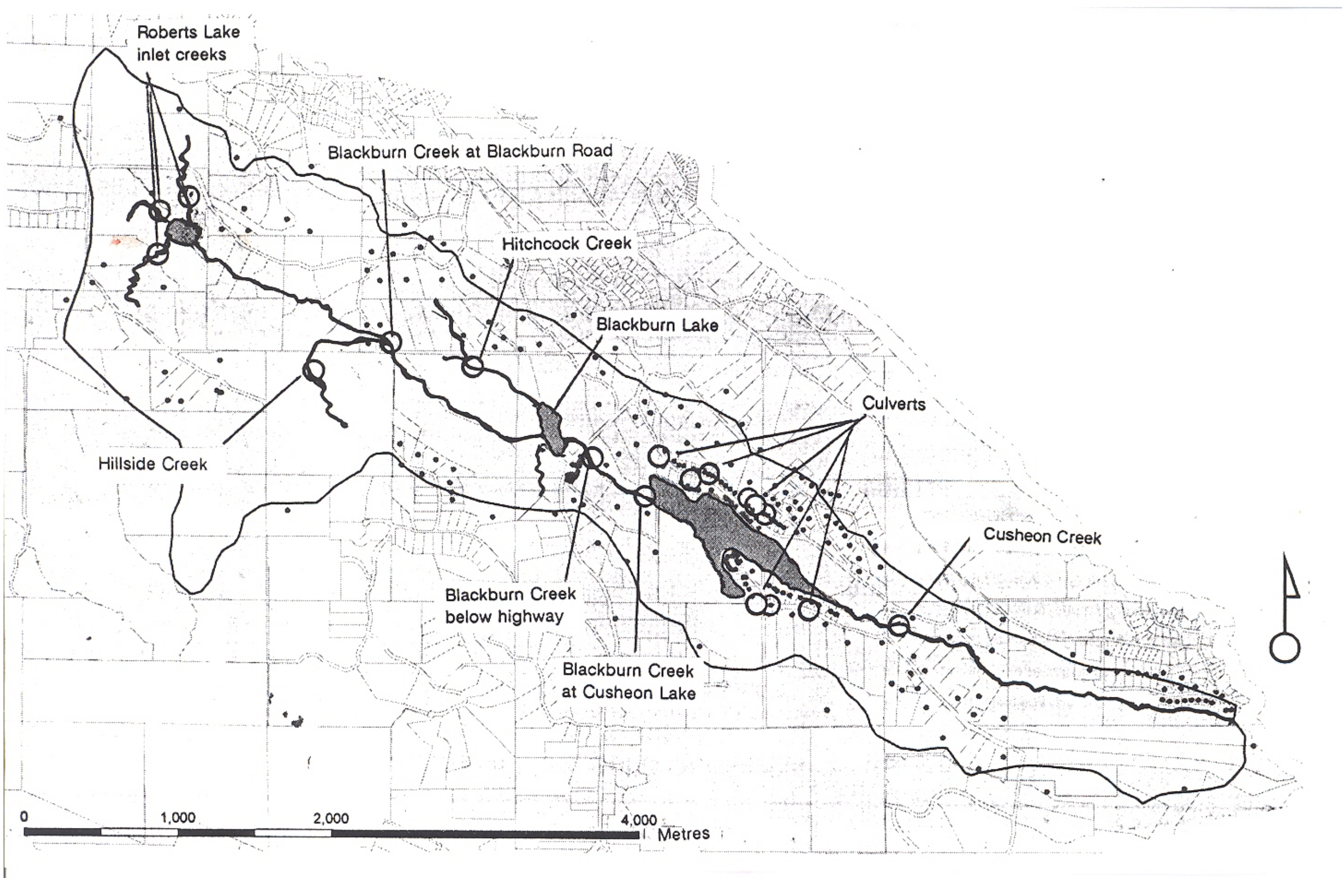

Figure 1. Location of sampling stations in the Cusheon basin. The dots indicate existing residences.

Hillside Creek was a small intermittent creek draining part of a hillside which had been clear-cut. This little waterway was assigned the name "Hillside Creek". It angles down a hillside between Roberts and BB Lakes, to the southwest of BB Road (Figure 1), and discharges into BB Creek. Approximately 35 hectares of the surrounding 65-hectare block of land had been clear-cut in 2001, i.e. four years before the sampling in this study. The area had been replanted with trees, but by the time of sampling, the land had grown up with a continuous and sturdy growth of ground-cover including small bushes, Salal and Oregon grape. There was very little bare soil remaining in the clear-cut area. Also, vegetation had been protected in strips along most of the intermittent watercourses.

Development drains were only sampled once. They were small channels of surface runoff from a road under construction, intended to serve a twelve-lot housing development. The road branched off Blackburn Road only 30 metres northwesterly of BB Creek, very close to the location “Blackburn Creek at Blackburn Road” in Figure 1. This service road was a major construction blasted and bulldozed along a hillside uphill from Blackburn Creek at distances of 40 metres or more. There were large piles of dirt along the new road during the rainy season of 2004-05. One runoff channel ran beside the new road to a ditch of Blackburn Road and thence flowed about 30 metres into Blackburn Creek. The other channel went down the hillside by an established drainage route, to Blackburn Creek.

Blackburn Creek at Blackburn Road was the major sampling point of a one-year study. Results reported here are from a report that offers daily values of flow and phosphorus at the location (Sprague 2007b). Samples and measurements of flow were taken at the culvert crossing the road.

Hitchcock Creek is a very small ditched intermittent creek that comes in from a northerly direction and crosses Blackburn Road 0.5 kilometres to the east of Blackburn Creek’s road crossing. It picks up a little drainage from the southerly side of Blackburn Road, and that is included in the sampling reported here. It then runs independently for half a kilometre and enters Blackburn Lake on its northerly side.

Lower Blackburn Creek is the section between Blackburn Lake and Cusheon Lake, near a modular-home park. There were two sampling points. One was called *BB Creek below highway*, taken in the section 30 metres downstream from the culvert carrying the outflow of Blackburn Lake across Fulford-Ganges Road. Although it might be thought that samples from this place would represent the water of Blackburn Lake, they did not. There was appreciable turbulence at the culvert outflow and the riffled section below that, which stirred up sediment, and thus increased the total phosphorus content of the water. The second site was 300 metres downstream, at the mouth of Blackburn Creek where it entered Cusheon Lake *(Blackburn Creek at Cusheon Lake)*.

These two sampling points were intended to evaluate septic drainage at 26 modular homes in Cedarview Park, close to Fulford-Ganges Road on the westerly bank of the creek. The septic fields can be expected to contribute a normal amount of phosphorus seepage through the soil to the creek. The amount depends on proximity to the creek, but this concentration of homes might be a significant source of phosphorus. The upper sampling point is upstream of any potential contribution from septic fields. The lower sampling point was well downstream, and any contribution would have been mixed across the creek at that point. Since there are no significant tributaries in that short stretch of creek, the two estimates of flow at the sampling points were averaged for any given day, and that value was used as the flow at both places. Usually the two estimates were close (e.g. on November 2, 133 and 132 L/sec).

Cusheon culverts was the name assigned to composite samples from nine culverts draining directly into Cusheon Lake. Six of them were on the northeasterly side of the lake, crossing underneath Cusheon Lake Road. The others were on the southwesterly side, crossing Horel Road or its right-of-way. Values reported here were taken from a separate report on these culverts (Sprague 2007d).

Top of Cusheon Creek. Occasionally, samples were taken here, downstream of the outlet of Cusheon Lake. The sampling point was the discharge of the culvert under Stewart Road. As in lower Blackburn Creek, the water samples do not adequately represent the water leaving Cusheon Lake, because there is turbulence in some sections between the lake and the sampling point, which would increase the suspended sediment. Sampling the actual outflow water would be difficult on foot, because it is in a diffuse marshy area grown up in bushes, with obscure flow channels.

Sampling times

The survey started in August of 2004. In this comparative study, it was only necessary to obtain a small set of samples at representative times of the wet season. Several sample runs were done at times of rainfall or just after a rainfall. Those are the times of concern for phosphorus runoff from the land. Some other sampling runs were done at typical winter flows.

The exact dates of sampling are shown in the Appendix. The first samples were taken on August 6 at the time of a rainfall and runoff, unusual in late summer and the first one after the dry period. The next assessments were on October 17 and 19, the first subsequent period that had rainfall events causing appreciable runoff. Thus, the study captured the first flushes of runoff from the land after the dry summer. This is important since these first flushes are relatively high in phosphorus (Sprague 2007b, d).

Single samples in each of November and December were also at the times of most concentrated rainfall during those months. Four sets of samples in January were taken during and after a particularly heavy runoff that was later judged to be a ten-year event (Sprague 2007b). During that event, the concentrations and loads of phosphorus in Blackburn Creek are not considered to represent a typical year, but they are nevertheless included here for comparison with the smaller creeks.

The declining runoff from the January event was followed by one sampling in early February, which was an unusually dry month. Five sets of samples in March centred on mild rainfall events and relatively low winter flow. One sample was in April, after which there was only light continuing rainfall. By April, flows were declining and relatively steady, phosphorus concentrations were lower for any given flow, and it was not considered necessary to continue sampling.

The snow and rainfall during this period are listed in Sprague (2007b). Most samples were collected in mid- to late morning or in early afternoon.

Measuring volume of flow

Flow in the creeks was measured at the same time as water samples were collected. A relatively straight and uniform section of creek was selected. Average depth and width were measured to calculate the cross-sectional area. The velocity of flow over a marked distance was assessed with a float and stopwatch, usually from several measurements. A standard factor of 0.75 was applied for bottom drag as recommended and explained by University of Washington (2005) and Sprague (2007b).

Flow reported for the Cusheon culverts is the total flow from all nine culverts leading directly to the lake from built-up areas. Flow was easily measured since each culvert discharged at a height above the downstream water surface, so a stopwatch was used to time the filling of a marked container. This was sometimes possible for low flows in other locations (Hillside, Hitchcock and Cusheon Creeks). Flow in BB Creek at BB Road was estimated by a careful standardization of volume, velocity and depth in the metal culvert (Sprague 2007b).

Water samples

Grab samples of water were taken for analysis of phosphorus. The procedures were the same as those reported in Sprague (2007b). Briefly, clean 250-mL plastic (Nalgene) sample bottles were supplied by MB Laboratories Ltd. of Sidney B.C. Bottles were rinsed twice with vigorous shaking, using small amounts of the water to be tested. The bottle was drained then filled with sample, allowing an air-space at the top. The bottle had been pre-labelled. The sample was frozen within three hours, and sets of samples were later carried to MB Laboratories, still frozen in a cooler.

Care was taken to get a representative sample of the flowing water, and to avoid any disturbance of bottom sediments. Sediment that was already suspended in the water was accepted as part of the sample except for two samples on October 17 which were subject to unrepresentative local turbulence (samples at Roberts ruts which flows into Roberts Lake, and Blackburn Creek below highway) . Those two samples were settled for one minute and decanted, using the decantate as the sample. Sediment was a major factor in the water of BB Creek at BB Road during the violent flooding runoff of January 17 - 23, and most of the measured total phosphorus was considered sediment-bound and unavailable to enrich the water for organisms (Sprague 2007b). However, the total phosphorus is reported here.

A single composite result is reported for all of the small Cusheon culverts which run into Cusheon Lake, and the reported concentration allows for the proportional flow in the various culverts. In other words, the reported concentration, multiplied by the total flow from all the culverts, would equal the actual loading to the lake (Sprague 2007d).

Analysis for phosphorus

Measurements were made by MB Laboratories Ltd. of Sidney B.C. Samples were analysed by a process called *Technicon*, with reported sensitivity of 0.3 micrograms per litre (hereafter called *parts per billion* or *ppb*). From time to time, "blind" replicate samples were supplied to the laboratory with fictitious names, and the resulting precision of analyses proved to be excellent. The average coefficient of variation was 4.2% for twelve sets of replicates (details in Sprague 2007b). Some of these replicates are reported here (see Appendix).

Cross-checking was also arranged with the B.C. Ministry of Environment. That ministry has made many more measurements of phosphorus in surface waters than any other group, and that applies also to the Cusheon watershed. It is important that the present measurements should be comparable to those of the ministry. Through the sponsorship of Deborah Epps, of the Ministry of Environment in Nanaimo, such a comparison of measurements was made. A single large sample was taken from Roberts Lake on March 20, split into six standard samples, and given an assortment of false names so that the laboratories did not know they were replicates. Three of the replicates were sent to MB Laboratories within a regular shipment. The three others were immediately sent in a cooler to Maxxam, the analytical laboratory used by the Ministry. Results for total phosphorus (TP) were 18.6, 19.1 and 19.2 for MB Laboratories and 21, 22, 23 ppb for the government contractor. The two sets of results are not statistically different (t-test) and are considered satisfactorily similar.

RESULTS WITH DISCUSSION

The first section assesses various creeks in the upper basin for the loads of phosphorus that they carry, in comparison to the loads carried into Cusheon Lake by Blackburn Creek. Comparisons are also made with the load at the major site, Blackburn Creek at Blackburn Road, in other words upstream of Blackburn Lake.

These comparisons are only intended to illustrate the relative importance of phosphorus sources around the basin. It does not mean that phosphorus in creeks of the upper basin flows right through to the bottom of the system -- there are various sinks and mixes along the way. For example, some of the phosphorus that enters Roberts Lake from its tributary creeks will stay in the lake, at least for a while, and the load that leaves the lake might be smaller than the load that enters.

Phosphorus loads into Roberts Lake

Results from the three little tributaries flowing into Roberts Lake are combined here, to assess the overall importance. The runoff that flows down the vehicle ruts is treated as if it were a natural creek. Samples were taken in these inputs on five occasions (Table 1).

Table 1. Comparison of phosphorus loads into Roberts Lake with the loads carried by Blackburn Creek at two places. One place compared is at Blackburn Road, upstream of Blackburn Lake, and the other place is at the mouth of Blackburn Creek where it discharges into Cusheon Lake.

Date	Station	Flow, L/sec	P. conc., ug/L		Total P. load,* gm/day	% of load at BB Road	% of load at Cush. L.
			Total P.*	Diss. P.			
2004 Oct. 17	Roberts N. Creek	0.057	30.6		0.15		1%
	Roberts ruts	0.34	58.8	21.4	1.73		7%
	Roberts W. Creek	0	--	--	0.00		0%
	Total Roberts input	**0.40**	**54.8**		**1.88**	**1%**	**8%**
	BB Creek at BB Road	15.4	103.0	39.8	137		
	BB Crk at Cusheon Lk.	2.12	135.0	--	24.7		
2004 Nov. 02	Roberts N. Creek	52.3	23.1	--	104		14%
	Roberts ruts	2.6	33.4	--	7.5		1%
	Roberts W. Creek	48.0	35.7	--	148		20%
	Total Roberts input	**103**	**29.2**		**260**	**50%**	**34%**
	BB Creek at BB Road	130.2	45.8	12.2	515		
	BB Crk at Cusheon Lk.	33	65.7	--	755		
2004 Dec. 10	Roberts N. Creek	113.5	21.4	--	210		14%
	Roberts ruts	5.25	29.6	--	13.4		1%
	Roberts W. Creek	50.4	36.7		160		10%
	Total Roberts input	**169**	**26.2**		**383**	**21%**	**25%**
	BB Creek at BB Road	332	64.7	18.7	1856		
	BB Crk at Cusheon Lk.	510	35.1	--	1547		
2005 Mar. 20	Roberts N. Creek	27.0	13.0	--	30.3		9%
	Roberts ruts	1.1	28.4	--	2.70		1%
	Roberts W. Creek	6.8	65.1	--	38.2		11%
	Total Roberts input	**34.9**	**23.6**		**71.3**	**31%**	**20%**
	BB Creek at BB Road	82.7	31.8	--	227		
	BB Crk at Cusheon Lk.	122	33.5	--	353		
2005 Mar. 26	Roberts N. Creek	35.8	15.7	--	48.6		20%
	Roberts ruts	2.32	21.0	--	4.21		2%
	Roberts W. Creek	24.0	57.3	--	119		49%
	Total Roberts input	**62.1**	**32.0**		**172**	**33%**	**71%**
	BB Creek at BB Road	179	33.5	--	519		
	BB Crk at Cusheon Lk.	190	14.7	--	242		

* Concentrations given for "Total Roberts input" are weighted average concentrations, in other words, the concentration that would prevail if all three inputs were combined.
Some values carry extra significant figures for purposes of calculation.

To generalize, the load to Roberts Lake was about one-third of the load into Cusheon Lake. That is surprisingly high considering the smaller sub-basin that drains into Roberts Lake.

Near the start of the wet season in October, the flows in the upper basin were slight, almost negligible, compared to those further down. Concentrations of phosphorus in the Roberts creeks were about 40 to 50% of concentrations at the two sites on BB Creek. Because of the small flows, the load into Roberts Lake was only 1% to 8% of the loads at the two downstream sites (Table 1).

For the rest of the winter and into early spring (November to March), the load into Roberts Lake became surprisingly large. Volumes of flow, broadly speaking, were about one-quarter to one-half of the flows at the downstream sites. Phosphorus concentrations, however, were mostly close to 30 ppb, and so they ranged from about one-half to approximately the same as the concentrations in BB Creek. The load of phosphorus going into Roberts Lake ranged from 20% to 70% of the loads in BB Creek. Averaging the four measurements during this winter period, the load into Roberts averaged 34% of the load in the BB Creek at BB Road, and 37.5% of the load that the creek carried into Cusheon Lake.

Flow in a creek draining a clear-cut hillside

“Hillside Creek” was sampled to assess the runoff of phosphorus from a hillside that was recovering from clear-cutting. As described in the Methods, there had been at least 35 hectares of hillside clear-cut in 2001, and the land was now well-covered with small bushes and other ground-cover.

Hillside Creek was relatively low in phosphorus in March, 2004. It appears that revegetation of the land over four years had effectively controlled erosion and runoff of phosphorus, at least in the springtime.

Only two samples were taken from this creek. Table 2 shows that its flow was a small fraction of the flow in BB Creek. On these occasions, its phosphorus *concentration* was about the same as in BB Creek or only half as high. The *loads* were only one-half of one percent of the load carried by BB Creek.

Table 2. Comparison of the phosphorus load in Hillside Creek with the load in Blackburn Creek at Blackburn Road. Hillside Creek drains an area which was clear-cut four years previously, and has revegetated with low bushes and other ground cover.

Date	Station	Flow, L/sec	P. conc., ug/L Total P.*.	Diss P	Total P. load,* gm/day	As % of load in BB Creek
2005 Mar. 02	Hillside Creek	0.25	8.95	--	0.19	**0.47%**
	BB Creek at BB Road	46.1	10.4	--	41.42	
2005 Mar. 19	Hillside Creek	0.2	9.60	--	0.17	**0.46%**
	BB Creek at BB Road**	21.7**	19.0 **	--	35.69**	

* Values carry more significant figures than warranted, for the purpose of initial calculations.
** On this day, the flow and concentration in Blackburn Creek were estimated from measurements on adjacent days (Sprague 2007b).

No sampling was done at other times of year, so it is not known whether the first autumn rainstorms and the wetness of winter resulted in a high runoff of phosphorus down Hillside Creek. It seems unlikely, from the results in March. If the creek had been eroding its banks seriously, there should have been some evidence of silt and increased phosphorus in March, but observations on both days noted “clear” water. The first sample on March 2 followed 7 mm of rain during 24 hours. That rain had been preceded by a three-week period of no rain. The rain of March 1-2 was enough to double the flow in BB Creek from 30 to 64 L/sec (Sprague 2007b). No doubt Hillside Creek also had an increase in runoff, which would have increased phosphorus if there had been bank erosion and/or runoff from bare land. However, the phosphorus concentration in Hillside Creek was only 9 ppb, low and similar to that in BB Creek. The second sample on March 19 was in a modestly wet period. Preceding the sample, there had been moderate rainfall of 5 mm on March 16 and 17. The flow in BB Creek had bumped upward by 8-fold, and the phosphorus concentration by 6-fold, but they had declined again by the time of the sample on March 19. It is notable that the phosphorus concentration in BB Creek on March 19 was double that of March 2, but the concentration in Hillside Creek had not increased.

This evidence suggests that the clear-cut hillside had healed relatively well in four years, as far as erosion and phosphorus runoff are concerned.

Development drains

Surface runoff from a road under construction was sampled once in April during a period of rainfall. The concentrations of total phosphorus in the two samples were 15 and 19 ppb, higher than the 12 ppb which was present in BB Creek at the same time, and considerably more than the 8 ppb in Hillside Creek (see directly above). However, the flows of these runoffs were small, so their total load was 1.3 grams/day, much less than the 169 g/d in BB Creek and 6 g/d in Hillside Creek.

This minor attempt at assessment indicates that the runoff might not be contributing much phosphorus to the surface waters in the Cusheon basin. However, it can only be considered a superficial assessment, done only once on only two runoff streams, among the many such small streams of runoff that probably existed. There might have been serious contributions of nutrient during the rains of autumn and winter, considering the large piles of soil that had been newly exposed.

Phosphorus in Hitchcock Creek

This small ditched creek was assessed since it carries a separate load of phosphorus to Blackburn Lake. It can be compared with Blackburn Creek at the nearby site on Blackburn Road, to get an appreciation of its fairly small contribution of phosphorus.

This was indeed a relatively small creek. The flow of Hitchcock Creek averaged 10% of the flow in BB Creek at BB Road, for the ten occasions when it was flowing and samples were taken. That can be calculated from the data in Table 3.

Overall, the phosphorus *concentrations* in Hitchcock Creek averaged only 72% of those in BB Creek. As would be expected from the averages for flow and concentration, the phosphorus *loads* carried by Hitchcock Creek averaged only 7.3% of the loads in BB Creek.

However the ten comparisons of concentrations and loads were extremely variable. Concentrations varied from about 5% to 130% of those in BB Creek. The loads varied from 0.2% to 24% of the Blackburn loads. The low proportion for loads was for October 19, early in the wet season when Hitchcock Creek was just beginning to flow with a very small amount of water. The high proportion was in February, when the amount of water flowing down Hitchcock Creek was fairly high and concentration of phosphorus was about equal to that in Blackburn Creek.

Table 3. Comparison of phosphorus concentration and load in Hitchcock Creek with those in Blackburn Creek at two places.

Date	Station	Flow, L/sec	P. conc., ug/L		Total P. load,* gm/day	% of conc. at BB Road	% of load at BB Road	% of load at Cush. L.
			Total P.*	Diss. P.				
2004 Aug. 06	Hitchcock Creek	0	--	--	0	0	0	0
	BB Creek at BB Road	3.1	103	97.7	27.59	--	--	--
2004 Oct. 17	Hitchcock Creek	0.48	129.0	--	5.35	95.6%	3.9%	21.6%
	BB Creek at BB Road	15.4	103.0	39.8	137.05	--	--	--
	BB Crk at Cusheon Lk.	2.12	135.0	--	24.73	--	--	--
2004 Oct. 19	Hitchcock Creek	1.76	5.1	--	0.77	4.9%	0.2%	9.2%
	BB Creek at BB Road	44.4	104.0	33.3	398.96	--	--	--
	BB Crk at Cusheon Lk.	2.13	45.7	--	8.41	--	--	--
2004 Nov. 02	Hitchcock Creek	5.1	38.3	--	16.88	83.6%	3.3%	2.2%
	BB Creek at BB Road	130.2	45.8	12.2	515.22	--	--	--
	BB Crk at Cusheon Lk.	133	65.7	--	754.97	--	--	--
2004 Dec. 10	Hitchcock Creek	66.3	42.0	--	240.59	64.9%	13.0%	15.6%
	BB Creek at BB Road	332	64.7	18.7	1855.91	--	--	--
	BB Crk at Cusheon Lk.	510	35.1	--	1546.65	--	--	--
2005 Jan. 17	Hitchcock Creek	73.0	190.0	--	1198.37	114.5%	17.1%	533%
	BB Creek at BB Road	488	166.0	23.8	6999.09	--	--	--
	BB Crk at Cusheon Lk.	94.3	27.6	15.9	224.87	--	--	--
2005 Jan. 18	Hitchcock Creek	98.0	46.1	--	390.34	30.1%	5.3%	39.1%
	BB Creek at BB Road	554	153.0	19.3	7323.44	--	--	--
	BB Crk at Cusheon Lk.	258	44.7	16.7	996.42	--	--	--
2005 Jan. 23	Hitchcock Creek	51.4	19.5	--	86.60	16.4%	1.6%	4.0%
	BB Creek at BB Road	540	119.0	--	5552.06	--	--	--
	BB Crk at Cusheon Lk.	379	65.6	10.5	2148.11	--	--	--
2005 Feb. 04	Hitchcock Creek	20.3	27.6	--	48.41	114.5%	23.7%	7.8%
	BB Creek at BB Road	98.3	24.1	--	204.68	--	--	--
	BB Crk at Cusheon Lk.	285	25.2	--	620.52	--	--	--
2005 Mar. 20	Hitchcock Creek	5.1	19.0	--	8.37	59.7%	3.7%	2.4%
	BB Creek at BB Road	82.7	31.8	--	227.22	--	--	--
	BB Crk at Cusheon Lk.	122	33.5	--	353.12	--	--	--
2005 Mar. 26	Hitchcock Creek	2.06	44.2	--	7.87	131.9%	1.5%	3.3%
	BB Creek at BB Road	179	33.5	--	518.10	--	--	--
	BB Crk at Cusheon Lk.	190	14.7	--	241.32	--	--	--
					Averages	72%	7.3%	63.8%
						(without Jan. 17-23)		(8.9%)

* Some values have kept more significant figures than warranted, for the initial calculations.

The phosphorus loads coming down Hitchcock Creek might also be compared to the loads of Blackburn Creek as it enters Cusheon Lake (last column of Table 3). The proportions are not particularly enlightening since the Blackburn values do not represent water running directly off the land, but instead represent water that has overflowed from Blackburn Lake, then raised some sediment as it flows down the creek.

The Hitchcock load on the ten occasions averaged 64% of the load going into Cusheon Lake. However, the value is biased by extremely high flows and concentrations in the upper creeks during January 17 to 25 (three samples in Table 3). That was the time of a 10-year storm and runoff, with extensive washouts and flooding. It was considered unrepresentative of a typical year (Sprague 2007b). The phosphorus content was apparently bound to relatively heavy sediment, which would probably settle out quickly in quiescent areas such as the shoreline vegetation where the creek enters a lake, and would probably be unavailable to organisms.

Removing those three sets of data, the average load in Hitchcock was about 9% of the load that entered Cusheon Lake from BB Creek, and that is considered a more representative estimate.

Apparent effect of the modular-home park

This part of the study attempted to assess a possible increase of phosphorus in lower Blackburn Creek, resulting from normal seepage from septic fields of a modular-home park.

There were two sampling stations, one slightly upstream of the park, and a second one about 300 metres downstream, where any contribution would have been well mixed into the creek.

The values in the creek were both confirmatory and indeterminate. A few measurements of *dissolved phosphorus* confirmed an earlier theoretical estimate of seepage. A larger number of values for total phosphorus (the standard item measured) were not useful because they showed wild variations in concentration, apparently caused by variable loads of suspended sediment.

Theoretically, properly-functioning septic fields at the modular-home park should contribute 7.79 kg of phosphorus per year to the creek, considering distances from the creek (Sprague 2007a). That would be 21.3 grams per day on the average.

Total phosphorus is the standard measurement in assessing lake enrichment, and that will be considered first. The nine sets of total phosphorus in Table 4 neither confirm nor contradict the earlier theoretical estimate.

Table 4 (second column from right) shows no clear pattern of change from the upper to the lower sampling station. Some changes were small, some large, while some were negative and some positive. Only a couple of the downstream changes in total phosphorus are similar in magnitude and direction, to the theoretical estimate of 21 grams increase. The other downstream changes are greatly different, and they run from a low of minus 189 grams/day to a high of 1467 g/d.

There does not appear to be an obvious reason why any of those estimates of changed total phosphorus should be considered more valid than others. A probable explanation of the variability is given below, following Table 4.

Table 4. Results of sampling at two points on lower Blackburn Creek to assess potential contributions of phosphorus from a modular-home park.

Date	Station	Flow, L/sec	P. conc., ug/L		Total P. load,* gm/day	Downstream change, load of Total P.	Downstream change, load of Diss. P.
			Total P.*	Diss. P.			
2004	BB Crk below highway	2.12	145.0	--	26.56		
Oct. 17	BB Crk at Cusheon Lk.	2.12	135.0	--	24.73	-1.83	--
2004	BB Crk below highway	133	64.6	--	742.33		
Nov. 02	BB Crk at Cusheon Lk.	133	65.7	--	754.97	12.64	--
2004	BB Crk below highway	510	68.4	--	3013.98		
Dec. 10	BB Crk at Cusheon Lk.	510	35.1	--	1546.65	1467.33	--
2005	BB Crk below highway	94.3	23.6	12.2	192.28		
Jan. 17	BB Crk at Cusheon Lk.	94.3	27.6	15.9	224.87	32.59	30.1
2005	BB Crk below highway	258	36.2	16.7	806.94		
Jan. 18	BB Crk at Cusheon Lk.	258	44.7	16.7	996.42	189.48	0
2005	BB Crk below highway	379	29.7	9.19	972.54		
Jan. 23	BB Crk at Cusheon Lk.	379	65.6	10.5	2148.11	1175.57	42.9
2005	BB Crk below highway	285	26.0	--	640.22		
Feb. 04	BB Crk at Cusheon Lk.	285	25.2	--	620.52	-19.70	--
2005	BB Crk below highway	122	32.9	--	346.79		
Mar. 20	BB Crk at Cusheon Lk.	122	33.5	--	353.12	6.33	--
2005	BB Crk below highway	190	26.2	--	430.78		
Mar. 26	BB Crk at Cusheon Lk.	190	14.7	--	241.70	-189.08	--

* Some values in the table carry more significant figures than warranted, for purposes of the initial calculations.

A probable explanation for divergent results between the two places is that erosion and/or stirring up of sediment was adding silt to the water, silt which carried additional bound phosphorus (measured as total phosphorus). Possibly this disturbance varied erratically between the two sampling stations. This seems the most likely explanation, somewhat supported by a tendency for the greater discrepancies to be associated with higher flows, as shown in the following tabulation.

Flow, L/sec	Downstream change in phosphorus load	Flow, L/sec	Downstream change in phosphorus load
2.12	- 1.83	190	- 189
94.3	32.6	258	189
122	- 6.35	285	- 19.7
133	12.64	379	1176
		510	1467

On the left side of the tabulation, four of the five smallest discrepancies associate with the four lower flows. On the right side, four of the largest discrepancies associate with the five higher flows. The association is weak, however, particularly because of the mixtures of positive and negative values.

From this, it is concluded that results for *total* phosphorus are highly erratic and do not contribute useful information on the possible contribution of phosphorus from the modular-home park.

Measurement of ***dissolved phosphorus***, however, gives some support to the theoretical calculation. Only three sets of values are available. As mentioned, total phosphorus is the standard measurement in this type of research, and budgetary restrictions meant that dissolved phosphorus could only be measured in selected samples.

The right-hand column of Table 4 shows the three assessments of downstream change in load of dissolved phosphorus. The values are 30.1, zero, and 42.9 grams per day. Two of the values are of the same magnitude and direction as the theoretical value of 21 g/d. There is no particular reason to value any of the three estimates more highly than the others, so an average can be calculated as 24.3 g/d, which is surprisingly close to the theoretical calculation.

There is some reason to credit the dissolved phosphorus measurements as valid assessments of the possible septic contributions. Any seepage through the soil from the septic fields *must have been carried* by water escaping to the surface of the soil or to the banks of the creek. By definition, that water-carried phosphorus would be in the soluble form. The adsorbable forms of phosphorus would have stayed behind, attached to soil particles. In fact, most phosphorus that comes from the land into surface waters is because of erosion, and the phosphorus is sorbed onto particles (silt), and travels with those particles. This is why control of erosion is important for reducing lake enrichment. (Table 4 shows that total phosphorus concentrations were two to six times higher than dissolved phosphorus in this part of the creek.)

The concentrations of dissolved forms of phosphorus would be expected to be less affected than the sorbed forms, by erosion and stirring up of sediments, and accordingly the dissolved phosphorus could be a better assessment of septic contributions. It is unfortunate that more measurements of dissolved phosphorus were not made.

From this, it is concluded that there was a contribution of dissolved phosphorus between the two sampling stations in this lower part of Blackburn Creek, and the contribution was of the general magnitude 24 grams per day.

The culverts flowing directly into Cusheon Lake

Nine culverts that delivered stormwater to Cusheon Lake were evaluated on the same general schedule as the creeks, with same-day data available for the different locations. The work is covered in a separate report (Sprague 2007d) but results from that report are summarized here for completeness. Comparisons were available for nine days from August 6 to March 26. (See data for the combined culverts in the Appendix; results for November 2 were not used because of an anomalous flow.)

As discussed at the end of this sub-section, the comparison of the culverts with Blackburn Creek does not present a satisfactory picture of the relative phosphorus contributions, because of major differences in the flow patterns. This comparison is made with BB Creek at BB Road because further downstream at the mouth of BB Creek, the influence of flow pattern would be even greater.

The amount of water flowing through the culverts averaged 13% of the flow in Blackburn Creek at Blackburn Road, on the same day and at about the same time of day. The phosphorus *concentrations* in the proportionally combined culvert water were similar to those in BB Creek for most of the winter and early spring (October 19 to March 26). The phosphorus *load* through the culverts was about one tenth of the load carried by BB Creek, comparing the same days during that winter period.

There was a different situation for the first two flushes of culvert runoff after the summer dry period (August 6 and October 17). They had very high concentrations of phosphorus, two or three times higher than in BB Creek. That was probably related to land development and other human activities in the built-up area served by the culvert drainage. During these first two flushes, the culvert load was equal to, or twice as great as, the load in BB Creek. Still, because of the small flows during these late summer/early autumn flushes, they contributed only a very small part of the yearly load.

Thus the culverts carried a load of phosphorus that was appreciable, but not major compared to the main creek in the watershed.

As mentioned, these comparisons of samples from the culverts with same-time samples from Blackburn Creek give an incomplete picture of the relative importance of phosphorus inputs. The culverts would have quite different flow regimes from those in Blackburn Creek. It would take a relatively short time for surface runoff to reach the culverts after a rainfall event, compared to the longer time for runoff to fill little creeks and flow down to reach Blackburn Creek. The time would be even longer for runoff to reach Blackburn Lake, build up, and overflow down to the mouth of Blackburn Creek at Cusheon Lake. After the rainfall event ceased, the flow in the culverts would drop off relatively quickly, while BB Creek would have a slower decline.

The variation in the relationships of the two sites can be seen in the original data in the Appendix, or in the report on these culverts (Sprague 2007d).

A complete assessment of relative phosphorus contributions would need many more samples than were used in this survey.

Cusheon Creek, the outlet of Cusheon Lake

This study was not designed to compare the inflow and outflow of phosphorus, to and from the lake. However, a few samples were taken near the beginning of Cusheon Creek, which receives the outflow from Cusheon Lake. Because there were only eight samples with comparisons to the inflow, the results were not very revealing (Table 5, and see *Critique* at the end of this sub-section).

Table 5. Measurements in Cusheon Creek, downstream from the outlet of Cusheon Lake, and in Blackburn Creek where it flows into Cusheon Lake.

Date	Station	Flow, L/sec	P. conc., ug/L		Total P. load,* gm/day	% of load at inlet creek
			Total P*	Diss. P.		
2005	BB Crk at Cusheon Lk.	133	65.7	--	755	--
Nov. 02	Start of Cusheon Creek	13.4	34.1	--	39.5	5%
2005	BB Crk at Cusheon Lk.	510	35.1	--	1547	--
Dec. 10	Start of Cusheon Creek	589	25.0	18.4	1272	82%
2005	BB Crk at Cusheon Lk.	94.3	27.6	15.9	225	--
Jan. 17	Start of Cusheon Creek	91.4	91.6	--	723	322%
2005	BB Crk at Cusheon Lk.	258	44.7	16.7	996	--
Jan. 18	Start of Cusheon Creek	652	30.1	--	1696	170%
2005	BB Crk at Cusheon Lk.	379	65.6	10.5	2148	--
Jan. 23	Start of Cusheon Creek	1294	27.5	--	3075	143%
2005	BB Crk at Cusheon Lk.	285	25.2	--	620.5	--
Feb. 04	Start of Cusheon Creek	433	18.2	--	681	110%
2005	BB Crk at Cusheon Lk.	122	33.5	--	353	--
Mar. 20	Start of Cusheon Creek	14.5	21.7	--	27.2	8%
2005	BB Crk at Cusheon Lk.	190	14.7	--	242	--
Mar. 26	Start of Cusheon Creek	30.3	36.3	--	95.0	39%

* Values in the table carry more significant figures than are warranted, for purposes of initial calculations.

The *volume of water* flowing out of the lake at the times of sampling varied from 14.5 litres per second in March to 1290 L/sec at the end of the major rainfall and flooding event in January (Table 5). For comparison, at the times of the eight samples, the inflow volumes were much less extreme, ranging from 94 L/sec to 510 L/sec (taken in Blackburn Creek where it enters Cusheon Lake). Oddly enough, the lowest of these inflows was on January 17, the first day of the winter rainstorm; apparently water was being stored in Blackburn Lake and had not yet created the massive overflow and flooding which occurred over the following days.

The *concentration of phosphorus* in upper Cusheon Creek ranged from 18 to 92 ppb but much of that probably represents sediment picked up in the initial part of the creek (see below). The mouth of Blackburn Creek (inlet to Cusheon Lake) had similar concentrations, ranging from 15 to 66 ppb. Average values would not be particularly meaningful in this situation. Four measurements of dissolved phosphorus showed less variation, from 10.5 to 18.4 ppb.

The *loads of phosphorus* in Cusheon Creek varied over an astonishing range, from 27 grams per day to 3,070 grams. If the larger rate had indeed prevailed all day, it would represent over 3 kilograms of phosphorus. The loads in the inflow were somewhat less extreme, ranging from 225 to 2150 g/day. On four of the eight days, there was a bigger phosphorus load entering the lake than leaving, and on four other days the reverse was true, with more leaving than entering.

Critique. These few grab samples cannot be used to assess the balance of inputs and outputs of phosphorus to and from Cusheon lake. If it were desired to do that, it would be necessary to have a much more intensive program of sampling, at least daily. One obvious reason for the variable data is that the relative inflows and outflows depended very much on whether the lake was filling up after a dry period, or emptying after a preceding storm event had over-filled it. Of course, the divergent inflow/outflow pattern also affected the load of phosphorus that was entering and leaving the lake.

An additional deficiency was that concentrations of phosphorus measured in Cusheon Creek did not represent the concentrations in water leaving the lake. Samples were taken below the culvert that carried the creek under Stewart Road. That is a good place to measure the volume of flow, which is otherwise a difficult proposition. The culvert is about 200 metres downstream of the actual outlet of the lake, the latter being located in an indefinite swampy area. The initial parts of the outlet creek have a mixture of slow and turbulent areas, which caused the water to pick up some silt with its accompanying load of phosphorus. Possibly the best way to assess the outflowing load of phosphorus from Cusheon Lake would be to sample phosphorus concentrations by boat in the surface waters near the outlet area, to represent the water that would flow out. Then the volume of outflow could be measured in the creek at the culvert. Alternatively, samples could be filtered to remove sediment and its phosphorus, and the various categories of phosphorus could be measured in more detail.

Concentrations in lakes

Samples were taken on six days in Roberts Lake. There had only been two previous measurements, carried out by the B.C. government (MWLAP 2003). Those previous values were 3.0 ppb for both June 1987 and August 1996. Such a low concentration might be found in an extremely pure soft-water lake in the rocks of the Canadian shield, but it must represent an error for this lake, and the previous values are not accepted here. Concentrations obtained in this study are given in the Appendix, and are shown in unified fashion in Table 6.

To obtain an average for total phosphorus in the lake, replicate values for a given day were averaged. Then the six daily values were averaged to obtain an overall average of 16.5   g/L (ppb) and that is taken as a representative value for Roberts Lake during the period when it is mixed.

For Blackburn Lake, the B.C. Ministry of Environment measured total phosphorus concentrations from January to March of 1981, a period when the lake was mixed. The results, provided courtesy of Deb Epps of the Ministry of Environment in Nanaimo, are as follows: for two days in January, 17 and 20 ppb; for three days in February, 13, 18, and 23 ppb; for one day in March, 12 ppb. One anomalous value of 123 ppb has been omitted; it probably resulted from sampling of suspended debris or algal cells. One value of 11.3 ppb was obtained in this study, for March 18, 2005 (see Appendix). Averaging these seven daily values provides a value of 16.3 ppb, and that is adopted as representative of Blackburn Lake during the late winter-spring season when the lake is mixed.

Table 6. Total phosphorus measured in Roberts Lake. "Blind" analyses signifies that replicate samples were sent to the analytical laboratory with false labels indicating diverse locations. Extra significant digits were retained in averages, then dropped after obtaining the overall average.

Date, Location	Total P, ug/L	Dissolved P, ug/L	Comments
2004. Oct. 17, end of dock	15.0	--	
2004. Nov.02, end of dock	20.1	--	
2004. Dec.10, end of dock	17.3, 18.3, 17.7 mean = 17.77	15.4	Replicates from single sample, with "blind" analyses
2005. Mar.20, near outlet	18.6, 19.1, 19.2 21, 22, 23 mean = 20.48	12.3 --	Replicates from a sample, "blind" analyses. First row by MB Laboratories, second row by govt. lab.
2005. Mar.26, outlet	15.8	--	
2006. Mar.18, end of dock, far shore, and outlet	10.4, 9.90, 9.96 mean = 10.09	--	
Overall average =	16.5		

One measurement was made in Cusheon Lake: 17.3 ppb on August 6. This value was used with many other measurements, in the detailed analysis and modelling of Cusheon Lake (Sprague 2007a).

ACKNOWLEDGEMENTS.

I thank Wayne Hewitt for persistence in sampling and Wiebke and Wilfried Ortlepp for dedicated sampling and recording at Blackburn Creek. Also thanked for assisting on some sampling runs are my wife Lois J. Sprague and daughter Chris A. Sprague. Funding for chemical analyses of phosphorus was provided by the Salt Spring Island Water Council under the auspices of the island Director for the Capital Regional District, Gary Holman, and by the Salt Spring Islands Trust with the assistance of Trustee Kimberly Lineger. Brett Korteling, GIS Coordinator for Islands Trust, created the background maps of the watershed.

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Appendix. Measured flows, phosphorus concentrations and loads in various waterways of the Cusheon watershed during 2004 - 2005. BB is an abbreviation for Blackburn.

Date	Station	Flow, L/sec	P. conc., ug/L Total P.*	P. conc., ug/L Diss. P.	Total P. load,* gm/day	% of load at Cush. L.**	Comments
2004	BB Creek at BB Road	3.1	103	97.7	27.59	--	First small flush with rain,
Aug. 06	Hitchcock Creek	0	--	--	0.00	--	after dry summer.
	Cusheon Lk. culverts	2.28	320.4	--	63.12	--	
	Cusheon Lake	--	17.3	--	--	--	
2004	Roberts N. Creek	0.057	30.6		0.15	1%	Not silty.
Oct. 17	Roberts ruts	0.34	58.8	21.4	1.73	7%	Roberts ruts and
	Roberts W. Creek	0	--	--	0.00	0%	BB Crk below highway
	Roberts Lake	--	15.0	--	--	--	had one-min. settling
	BB Creek at BB Road	15.4	103.0	39.8	137.05	554%	then supernatant tested.
	Hitchcock Creek	0.48	129.0	--	5.35	22%	Not silty.
	BB Crk below highway	2.12	145.0	--	26.56	107%	
	BB Crk at Cusheon Lk.	2.12	135.0	--	24.73	100%	Fairly clear.
	Cusheon Lk. culverts	6.72	104.0	33.3	60.38	244%	
2004	BB Creek at BB Road	44.4	104.0	33.3	398.96	4744%	
Oct. 19	Hitchcock Creek	1.76	5.1	--	0.77	9%	
	BB Crk at Cusheon Lk.	2.13	45.7	--	8.41	100%	
	Cusheon Lk. culverts	2.89	206.0	--	51.44	612%	
2004	Roberts N. Creek	52.3	23.1	--	104.38	14%	
Nov. 02	Roberts ruts	2.6	33.4	--	7.50	1%	
	Roberts W. Creek	48.0	35.7	--	148.06	20%	
	Roberts Lake	--	20.1	--	--	--	
	BB Creek at BB Road	130.2	45.8	12.2	515.22	68%	
	Hitchcock Creek	5.1	38.3	--	16.88	2%	
	BB Crk below highway	133	64.6	--	742.33	98%	
	BB Crk at Cusheon Lk.	133	65.7	--	754.97	100%	
	Cusheon Lk. culverts	9.59	27.9	--	23.12	3%	
	Start of Cusheon Creek	13.4	34.1	--	39.48	5%	
2004	Roberts N. Creek	113.5	21.4	--	209.86	14%	
Dec. 10	Roberts ruts	5.25	29.6	--	13.43	1%	
	Roberts W. Creek	50.4	36.7		159.81	10%	Blind duplicate samples,
	Roberts Lake	--	17.8	15.4	--	--	for Roberts W. Creek =
	BB Creek at BB Road	332	64.7	18.7	1855.91	120%	TP = 36.5 and 36.9.
	Hitchcock Creek	66.3	42.0	--	240.59	16%	For Roberts Lake =
	BB Crk below highway	510	68.4	--	3013.98	195%	Tp = 17.3 and 18.3
	BB Crk at Cusheon Lk.	510	35.1	--	1546.65	100%	
	Cusheon Lk. culverts	47.6	40.8	--	167.80	11%	
	Start of Cusheon Creek	589	25.0	8.4 1	1272.24	82%	

2005 Jan. 17	BB Creek at BB Road	488	166.0	23.8	6999.09	3112%	Jan. 17 represents the
	Hitchcock Creek	73.0	190.0	--	1198.37	533%	start of a 10-year run-
	BB Crk below highway	94.3	23.6	12.2	192.28	86%	off event from rain and
	BB Crk at Cusheon Lk.	94.3	27.6	15.9	224.87	100%	snow-melt. It persisted
	Cusheon Lk. culverts	77.5	123.0	--	823.61	366%	until Jan. 23, then flows
	Start of Cusheon Creek	91.4	91.6	--	723.36	322%	tapered off.
2005 Jan. 18	BB Creek at BB Road	554	153.0	19.3	7323.44	735%	
	Hitchcock Creek	98	46.1	--	390.34	39%	
	BB Crk below highway	258	36.2	16.7	806.94	81%	Muddy, did not decant.
	BB Crk at Cusheon Lk.	258	44.7	16.7	996.42	100%	Muddy, did not decant.
	Cusheon Lk. culverts	111	52.3	--	499.77	50%	
	Start of Cusheon Creek	652	30.1	--	1695.62	170%	
2005 Jan. 23	BB Creek at BB Road	540	119.0	--	5552.06	258%	Major flooding, highway.
	Hitchcock Creek	51.4	19.5	--	86.60	4%	Fairly clear sample.
	BB Crk below highway	379	29.7	9.19	972.54	45%	Muddy, did not decant.
	BB Crk at Cusheon Lk.	379	65.6	10.5	2148.11	100%	Muddy, did not decant.
	Cusheon Lk. culverts	70.4	24.2	--	147.20	7%	
	Start of Cusheon Creek	1294	27.5	--	3074.54	143%	Muddy, did not decant.
2005 Jan. 26	BB Creek at BB Road	91.5	29.5	--	233.22	--	
	BB Crk below highway	472	29.2	--	1190.80	--	
	Start of Cusheon Creek	1205	--	--	--	--	
2005 Feb. 04	BB Creek at BB Road	98.3	24.1	--	204.68	33%	
	Hitchcock Creek	20.3	27.6	--	48.41	8%	
	BB Crk below highway	285	26.0	--	640.22	103%	Fairly clear.
	BB Crk at Cusheon Lk.	285	25.2	--	620.52	100%	Fairly clear.
	Cusheon Lk. culverts	13.2	20.4	--	23.27	4%	
	Start of Cusheon Creek	433	18.2	--	680.88	110%	
Feb. 10	Cusheon Lk. culverts	13.0	11.4	--	12.80	--	
2005 Mar. 02	Hillside Creek	0.25	8.95	--	0.19	--	Clear.
	BB Creek at BB Road	46.1	10.4	--	41.42	--	
	Cusheon Lk. culverts	2.68	--	--	--	--	
2005 Mar. 18	Roberts Lake	--	10.1	--	--	--	Roberts Lake, 3 places,
	BB Lake, end of dock	--	11.3	--	--	--	TP = 10.4, 9.90, 9.96
2005 Mar. 19	Hillside Creek	0.2	9.60	--	0.17	--	Clear.
	BB Creek at BB Road	21.7	--	--	--	--	
	Cusheon Lk. culverts	2.13	52.4	--	9.64	--	
2005 Mar. 20	Roberts N. Creek	27.0	13.0	--	30.33	9%	Roberts Lake had 6 true
	Roberts ruts	1.1	28.4	--	2.70	1%	replicate samples,
	Roberts W. Creek	6.8	65.1	--	38.25	11%	TP = 18.6, 19.1, 19.2
	Roberts Lake	--	20.5	12.3	--	--	from regular lab,
	BB Creek at BB Road	82.7	31.8	--	227.22	64%	and 21, 22, 23 from
	Hitchcock Creek	5.1	19.0	--	8.37	2%	contractor for B.C. govt.
	BB Crk below highway	122	32.9	--	346.79	98%	
	BB Crk at Cusheon Lk.	122	33.5	--	353.12	100%	Hitchcock Creek had
	Cusheon Lk. culverts	4.9	40.8	--	17.41	5%	replicate samples,
	Start of Cusheon Creek	14.5	21.7	--	27.19	8%	TP = 18.7, 19.2

2005 Mar. 26	Roberts N. Creek	35.8	15.7	--	48.56	20%	
	Roberts ruts	2.32	21.0	--	4.21	2%	
	Roberts W. Creek	24.0	57.3	--	118.82	49%	
	Roberts Lake (outlet)	38.8	15.8	--	--	--	
	BB Creek at BB Road	179	33.5	--	519.26	215%	
	Hitchcock Creek	2.06	44.2	--	7.87	3%	
	BB Crk below highway	190	26.2	--	430.78	178%	
	BB Crk at Cusheon Lk.	190	14.7	--	241.70	100%	
	Cusheon Lk. culverts	11.1	35.0	--	33.57	14%	
	Start of Cusheon Creek	30.3	36.3	--	95.03	39%	
2005 Apr. 02	Hillside Creek	8.9	7.81	--	6.01	--	
	Devt. runoff at road	0.28	19.4	8.59	0.47	--	
	Devt. runoff channel	0.63	15.0	8.49	0.82	--	
	BB Creek at BB Road	166	11.8	--	169.04	--	
2006 Mar. 18	Roberts Lake dock	--	10.4	--	--	--	
	Roberts Lake far shore	--	9.9	--	--	--	
	Roberts Lake outlet	--	9.96	--	--	--	
	BB Lake, end of dock	--	11.3	--	--	--	

* Values in the table carry more significant figures than are warranted. They were retained in calculations, but dropped when expressing the final results. One decimal place was retained for all phosphorus concentrations in the table, and two decimal places for all loads, because it allows the eye to make more rapid comparisons of calculations.

** This is the percentage of the total phosphorus load carried by Blackburn Creek at its mouth, where it enters Cusheon Lake. The load to the lake from the culverts is not part of that Blackburn Creek load, nor is the load carried by the outlet of Cusheon Lake (i.e. Cusheon Creek), but the percentages are given for purposes of comparison.